Saskatchewan Agriculture and Food

Phosphorus Fertilization in Crop Production

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Plant P

Phosphorus (P) is essential for plant growth, and is required in large amounts by plants. P fertilizer is needed on about 85 per cent of Saskatchewan cropland. Saskatchewan soils tend to be low in plant available P, and soil test summaries indicate more than 80 per cent of fields would benefit from P addition.

Plants need P throughout their life cycle, but especially during early growth stages for cell division. P is mobile in the plant, so P absorbed during early growth is later redirected for use in seed formation. Cereals, for example, rely heavily on the P taken up in the first four weeks of growth for crop establishment, tillering and final yield.

Plants absorb P as orthophosphate ions ($H_2PO_4^-$ and HPO_4^{2-}). Phosphate fertilizer is often referred to as P fertilizer.

Table 1. Phosphate removal (lb. P_2O_5/ac.) by selected Saskatchewan crops.

Crop	Yield bu./ac.	Grain lb. P_2O_5/ac.	Straw lb. P_2O_5/ac.	Total lb. P_2O_5/ac.
Wheat	40	21-26	8-9	29-35
Barley	60	30-37	10-12	40-49
Canola	35	33-40	13-17	46-57
Flax	24	14-17	4-5	18-22
Pea	50	31-38	7-8	38-46
Lentil	30	17-20	5-7	22-27
Alfalfa	2 tons	-	-	25-30
Corn Silage	5 tons		57-70	

Note: P content of fertilizer is expressed as P_2O_5 equivalent, even though no P_2O_5 occurs in fertilizer or soil. The P_2O_5 designation is a standard expression of relative P content. To convert P_2O_5 to P, multiply by 0.43.

Phosphorous deficiency is often difficult to see unless normal plants are available for comparison. The first sign is stunted plant growth. With severe deficiency, dead areas may develop on leaf tips, or stems. Older leaves will be affected before younger ones. A red to purple colour may be seen on young P-deficient cereals and grasses, especially during low temperatures (e.g. cool nights).

Soil P

Saskatchewan soils are inherently low in available phosphorus. Total P ranges from 400 to 2,000 lb./ac. in the top six inches of soil, but only a very small amount of the total P is available to the crop during a growing season.

About half the total P is present in organic forms and half in soluble and insoluble mineral forms, with only a small amount being plant available. As available P is used by the crop, some of the total P will very slowly be converted to available P. However, this process is too slow to meet the P demand of high yielding crops. Although crops can sometimes be grown for a few years without adding phosphate fertilizer, yields sooner or later begin to decline.

P Fertilization

Phosphorus is relatively immobile (moves very little) in the soil. Thus, it will not leach like nitrogen and sulphur, or be carried to plant roots by soil water. Furthermore, P from phosphate fertilizer will readily react with soil minerals making it less plant available.

When granular phosphate fertilizer is added to moist soil, it quickly dissolves releasing orthophosphate ions to the soil solution. Most liquid P fertilizer is ammonium polyphosphate, which when added to soil reacts with water to form orthophosphate. Over time, these ions react with calcium and other ions forming less plant available P compounds. No difference has been recorded in crop response to dry versus liquid fertilizer P formulations.

Manures are a source of inorganic and organic P. Organic P must be mineralized to orthophosphate to become plant available. Some manure, especially solid manures, have a low Nitrogen to Phosphorus (N:P) ratio relative to crop requirements, so application of manure alone to match the crop N requirement can lead to P build up. Refer to Saskatchewan Agriculture and Food's farm fact Managing Manure as a Fertilizer.

Most crops recover only 10 to 30 per cent of the P in fertilizer the first year following application. Recovery varies widely depending on soil type and conditions, the crop grown, and application method. However, Saskatchewan research has shown that the newly formed "less available P compounds" are more plant available than the "native soil P minerals". Thus, crops can continue to recover fertilizer P for several years after application.

P availability is dependent on several factors.

- Soil texture: soils high in clay content fix more P than those with less clay.
- Calcium carbonate content: more P is converted to the 'less available P compounds' in soils containing more calcium carbonate
- Soil temperature: low soil temperature will reduce P availability by slowing the movement of P from the soil to the root and by reducing the mineralization of organic matter to plant available P.
- Soil moisture: P is more plant available with 'good' soil moisture.
- Soil pH: P is most plant available between pH 6.5 and 7.0.
- Plant root type: plants with fibrous roots explore more soil volume in the zero to six inch depth than tap roots, and thus are better able to recover P.
- Microorganisms: Soil micro-organisms can immobilize P while breaking down organic matter, making it temporarily unavailable. Other microorganisms form associations with plant roots which increase the surface area of roots and their access to P. Others discharge acids into the soil which can help to solubilize some P minerals (see the discussion on JumpStart®.)

JumpStart®

Phosphorus solubilizing fungi such as JumpStart® is a microbial seed inoculant registered for use on many crops. The active ingredient is the spores of a naturally occurring soil fungus (*Penicillium bilaii*). Some formulations for legumes contain the same fungal spores in addition to a nitrogen fixing *Rhizobium* bacteria.

JumpStart® can increase the availability of fertilizer P and soil P to crops during the growing season. When soil test P level is low, JumpStart® can make available the equivalent of at least 10 lb./ac. of applied phosphate when applied with at least 10 lb./ac. of phosphate fertilizer. When soil test P level is high and only 10 to 15 lb./ac. of phosphate fertilizer is recommended, JumpStart® can replace the application of this amount of phosphate.

In general, JumpStart® increases P uptake whenever P fertilizer increases P uptake. This may not be the case in strongly acid soils (pH <5.5), extremely sandy soils, i.e. where calcium- bond P is not dominant.

Phosphorus solubilizing microorganisms aid P utilization efficiency, but are not a substitute for a long term P fertilizer program, because they have no residual benefit. Fields should be monitored by soil testing to ensure that adequate background levels of P are available.

When the amount of P fertilizer that can safely be applied with the seed is less than the amount that is recommended, seed inoculation can offer added flexibility.

Crop Response

Crop response to phosphate fertilizer can be quite variable from one year to the next because of the many factors which influence P availability and crop growth. Also, increased P uptake by the plant does not necessarily provide for an increase in yield. However, hundreds of Saskatchewan trials have shown, in the long term, an average wheat yield response of about 5 bu./ac. to 20 lb. actual seed placed phosphate fertilizer per acre. Trials have also shown the crop response may be as high as 10 bu./ac.

Granular monoammonium phosphate (MAP) (e.g. 12-51-0 or 11-55-0) is the most common P fertilizer used in Saskatchewan. The most common liquid P fertilizer is ammonium polyphosphate (APP) (e.g. 10-34-0). They contain nitrogen as well as P in the phosphate form.

Diammonium phosphate (DAP) (e.g. 18-46-0) is occasionally found in southern Saskatchewan. However, the P in DAP is less available than the P in MAP and APP on high pH soils. Most Saskatchewan soils have a high pH. Also, not as much DAP can be safely placed with the seed without causing germination or seedling injury.

Table 2. Banded phosphate fertilizer recommendations for zero to six inch samples collected from dryland fields with normal moisture conditions*

Soil Test P (lb./ac.)	Actual P_2O_5 Fertilizer (lb./ac.)			Probability** of a yield response (%)
	Low moisture conditions	Average moisture conditions	High moisture conditions	
0-10	20-25	35-40	40-45	>75
11-20	15-20	25-30	30-35	50-75
21-30	10-15	20-25	25-30	50
31-60	5-10	15-20	20-25	25-50
>60	5-10	5-10	5-10	less than 25

** for 0 to 12 inch samples, multiply the soil test P for the O to 12 inch sample by 0.65 in the Brown soil zone, by 0.75 in the Dark Brown and Black soil zones or by 0.60 in the Gray soil zone, to convert to 0 to 6 inch samples.*

*** means likelihood*

Application Methods

Phosphate fertilizer can be applied in the following ways:

- **Seed placed** fertilizer is the placement of fertilizer directly in the seed row with the seed. Fertilizer will be more or less in a band depending on the width of spread of fertilizer and seed.

  For cereal crops, 50 lb./ac. of actual phosphate (P_2O_5), the maximum annual recommendation, can be safely seed placed. For other crops see Table 3. Exceeding the safe rates can cause reduced germination and seedling injury. For more information on safe rates see the Farm Facts bulletin entitled Guidelines for Safe Rates of Fertilizer Applied with the Seed.

Table 3. Maximum safe rates of seed placed monoammonium phosphate fertilizer (lb. actual P_2O_5/ac.)*

Crops	lb. actual P_2O_5/ac.
Flax, Pea, Forages (alfalfa and bromegrass)	15
Lentil, Mustard, Chickpea	20
Canola	25
Canary Seed, Pinto bean	30
Faba bean	40
Cereals	50

**divide the actual lb of P_2O_5 by, for example 0.51 get lb of 12-51-0 product needed per acre.*
*** rates are based on knife openers with a one inch spread, nine inch row spacing and good to excellent soil moisture.*

- **Banded near the seed** refers to the placement of fertilizer in a band near, but not with the seed during the seeding operation. With side banding, the fertilizer is placed one to two inches to the side, or one to two inches to the side and one to two inches below the seed. With below banding, the fertilizer band is one to two inches directly below the seed.

  Whereas a limited amount of fertilizer can be safely seed placed, all (dry and liquid) recommended fertilizer can generally be safely banded near the seed provided at least

one to two inches (depending on moisture conditions) of firm soil separates the seed and fertilizer.

- **Banded** fertilizer is placed in narrow bands in the soil in fall or in spring, prior to seeding. This method is not recommended as the only placement for P fertilizer because placing the P more than 1.5 inches from the seed can limit early supplies of available P.

  The availability of P is considerably enhanced when it is applied in a common band with N, often referred to as a dual N-P band. Dual N-P banding all the fertilizer prior to seeding works best on warmer soils. On soils that are cooler at seeding, or on soils that are quite P deficient, all or at least some of the P should be applied with, or near the seed. If very high amounts of N are applied in a dual N-P band at, or just prior to seeding, some delay of P uptake may occur.

- **Broadcasting and incorporating** low rates of phosphate fertilizer is not as effective as placing phosphate with the seed or banding phosphate because of the likelihood of rapid conversion to less available P compounds. However, as application rates increase, the difference between application methods decreases.

  Broadcasting and incorporating large one-time applications of phosphate fertilizer to build back-ground soil P levels has proven effective on Saskatchewan soils. A low rate of annual seed placed phosphate is often still needed for optimum yields.

  Top dressing phosphate is acceptable for established forages. Dribble or coulter banding and nesting in established forages may increase P efficiency.

This bulletin has been reviewed by the Saskatchewan Soil Fertility Committee.

For more information:
Contact the Agriculture Knowledge Centre at 1-866-457-2377.